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U. S DEPARTMENT OF AGRICULTURE,

DIVISION OF ENTOMOLOGY—BULLETIN NO. 32, NEW SERIES.

L. O. HOWARD, Entomologist.

INSECT ENEMIES OF THE PINE IN THE BLACK HILLS FOREST RESERVE.

AN ACCOUNT OF RESULTS OF SPECIAL INVESTIGATIONS, WITH RECOMMENDATIONS FOR PREVENTING LOSSES.

PREPARED UNDER THE DIRECTION OF THE ENTOMOLOGIST.

By A. D. HOPKINS, Ph. D.,

Vice-Director and Entomologist of the West Virginia Agricultural Experiment Station.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Division of Entomology,
Washington, D. C., January 22, 1902.

Sir: In the temporary absence of Dr. L. O. Howard, Chief of the Division of Entomology, I have the honor to transmit herewith the manuscript of a paper entitled "Insect Enemies of the Pine in the Black Hills Forest Reserve," by Dr. A. D. Hopkins, Entomologist of the West Virginia Agricultural Experiment Station. The extensive losses occasioned in recent years by insects to forest lands in various portions of the United States, and particularly in the North and Northwestern regions, have attracted great attention, and have necessitated investigations as to the character of the injury in order that the most appropriate methods of control may be advised. The present contribution is the third of a series bearing upon the insect enemies of coniferous trees, and comprises a summarized account of results of a special investigation that was made during the year 1901 under instructions from this Division and with the cooperation of Mr. Gifford Pinchot, Forester of this Department, together with a consideration of valuable suggestions for preventing losses, based upon studies by Dr. Hopkins extending over a number of years. I recommend its early publication as Bulletin No. 32, new series, of this Division.

Respectfully,

F. H. Chittenden,
Acting Entomologist.

Hon. James Wilson,
Secretary of Agriculture.

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INSECT ENEMIES OF THE PINE IN THE BLACK HILLS FOREST RESERVE.

REQUEST, AUTHORIZATION, AND INSTRUCTIONS.

The work herein reported was undertaken by request of Mr. Gifford Pinchot, Chief of the Bureau of Forestry, under authorization from the honorable Secretary of Agriculture and instructions from Dr. L. O. Howard, Chief of the Division of Entomology.

THE INVESTIGATING TRIP.

The investigations were conducted, in company with Mr. Pinchot and his chief field assistant, Mr. Griffith, on September 1 to 4, 1901, along a route traversed through the reserve from Spearfish, via Iron Creek, Bear Gulch, and Cement Ridge, South Dakota, Rifle Pit, Wyoming, and Spearfish Creek, to Lead, S. Dak.

THE CONDITIONS OBSERVED.

Vast numbers of rock pine (*Pinus ponderosa scopulorum*) that were dying, or had died within recent years, of sizes ranging in diameter from 4 inches to the largest trees, were observed along the route. The dying trees occur in clumps of from a few examples to many hundreds, and in some sections, as viewed from the summit of Cement Ridge and other favorable points, the dying, recently dead, and old dead trees cover large areas.

THE AMOUNT OF DEAD TIMBER.

Mr. H. S. Graves[a] estimated in 1897 that about 3,000 acres of pine in the Black Hills Forest Reserve had been killed. Further data furnished by the Bureau of Forestry show that the actual amount of dead timber, as determined by Mr. Griffith and party in a detailed survey of the timber resources of the reserve in 1901, is, "An average stand of 1,956 feet board measure of bug-killed timber on 116,000 acres, giving a total of 226,890,000 feet board measure."

HISTORICAL REFERENCES.

It is the general opinion among settlers and others who have had an opportunity to note the conditions affecting the pine that the dying timber commenced to attract attention about six or seven years ago, or about 1895.

[a] Nineteenth Annual Report U. S. Geological Survey, 1897–98, Part V, p. 87.

The evidence found by the writer in old dead standing and felled trees indicates that the pine-destroying beetle has been present for a much longer time. It was also evident that much of the devastation supposed to have been caused by forest fires was caused, primarily, by insects.

Mr. Graves, in his exhaustive report on the Black Hills Forest Reserve,[a] refers, on page 87, to insects and the dead pine timber as follows:

On the high limestone divide, from near Crook Tower to the head of Little Spearfish Creek, there are numerous patches of dead and dying timber. These patches are usually rectangular in shape and follow the tops of the divide and ridges, or run lengthwise up and down the slope. This forest has for the most part not been lately burned, and there is a heavy matting of litter and humus on the ground. The injury is confined to the limestone formation and to high elevations. The trees are in many cases second growth and apparently perfectly thrifty. This injury is probably caused by insects. On all dead and dying trees examined were found bark borers, a species of the Scolytidæ, working under the bark. In most cases the leaves were clinging to trees which had been dead for several seasons. While these borers do not, as a rule, attack vigorous trees, no other cause of the death of this timber could be found.

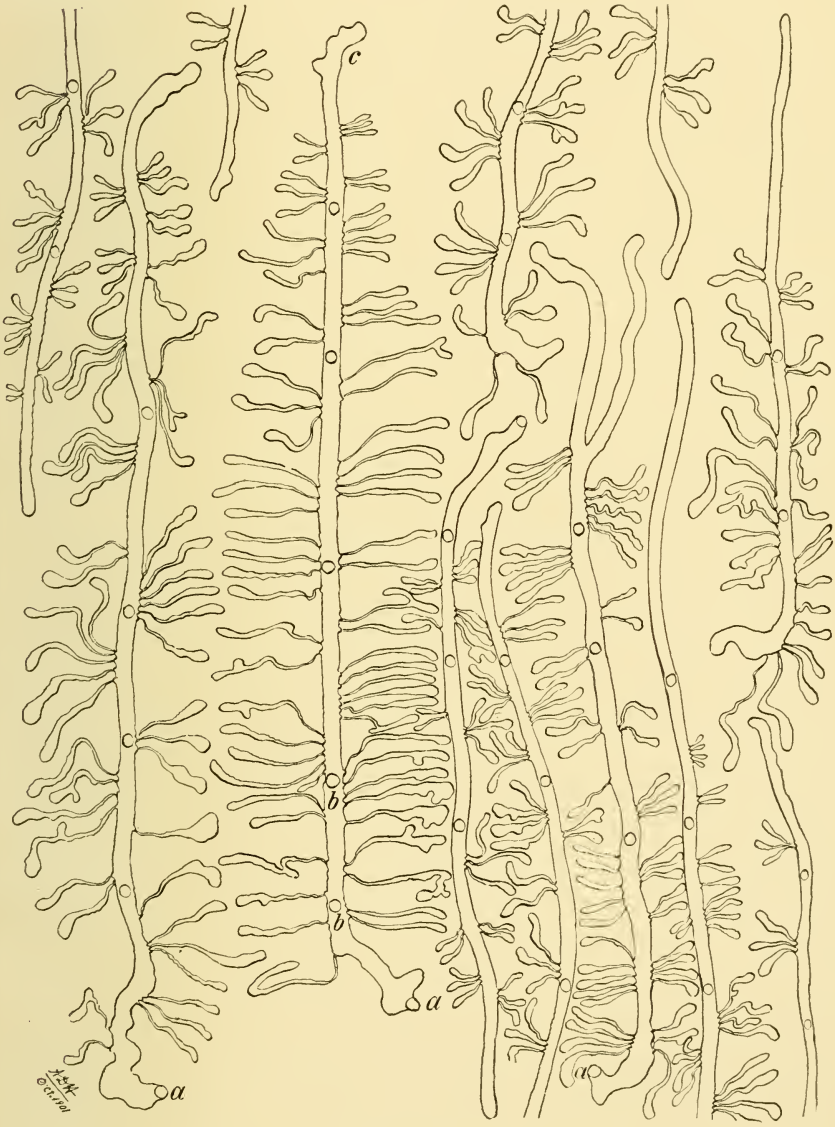
Mr. H. E. Dewey, writing to the Division of Entomology from Lead, S. Dak., on August 12, 1899, stated:

* * * There have been none in the trees this year until last Wednesday, the 9th. On that day there was a southwest wind, and a swarm of them came. My dwelling is in what was a grove of young native Black Hills pines. The bugs settled on the house like a plague of locusts. At night they left the house and scattered about. I have examined the trees, and with one exception do not find that they attacked them. This one excepted tree is a sight. Hundreds of bugs settled on it during the night, and by morning they had buried themselves out of sight in the trunk. As they bored their way in, the dust from their boring, which was very fine, filtered out from the top to the bottom of the tree like fine sawdust, and fell about the tree on the ground. They could be plainly heard at their work as they bored into the wood. The tree was a vigorous young pine about 15 feet high and 6 inches in diameter at the ground, and there is no apparent reason why they should select it more than others. Last year they were here in June.

The following copy of a letter addressed to the Department of the Interior, Division of Forestry, was submitted to the author from the Division of Entomology, with a specimen of the insect, which, together with the specimens sent with Mr. Dewey's letter, formed the material from which the species was named and descriptive notes were made. The letter is dated Piedmont, S. Dak., August 14, 1898, and reads as follows:

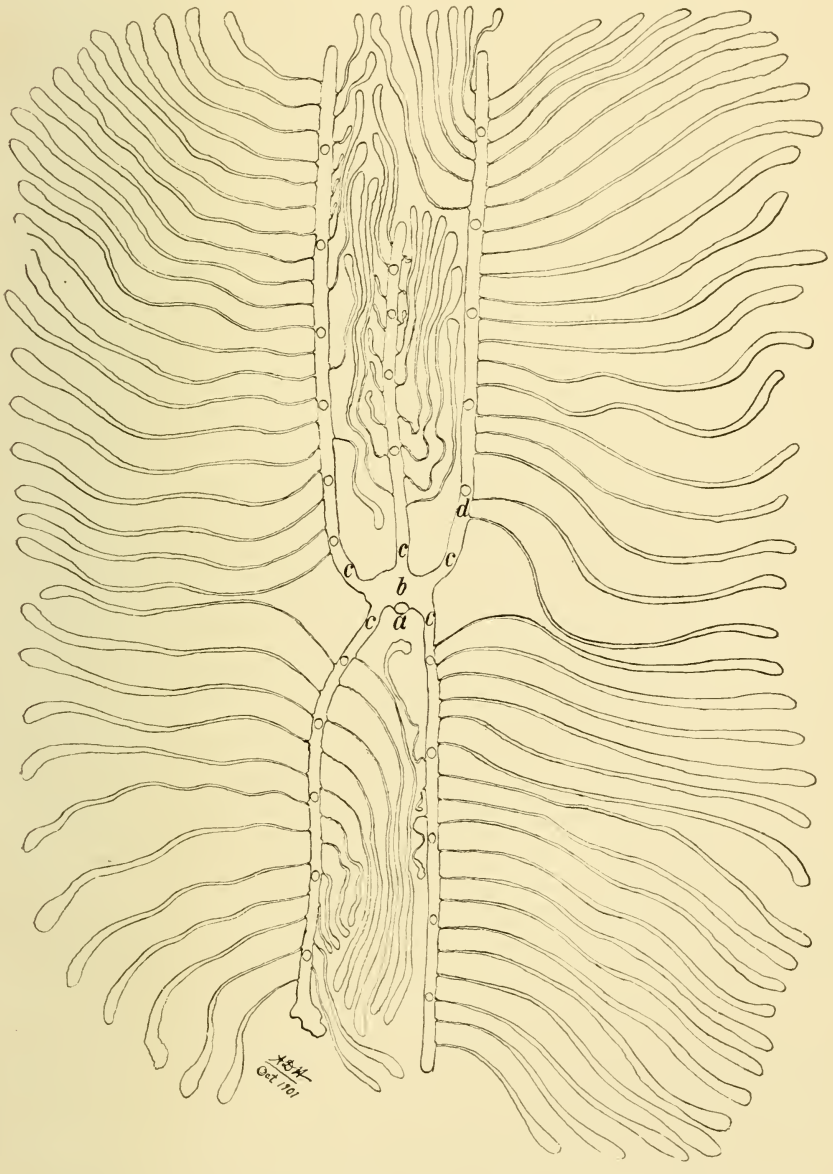
Many of the pine trees in this vicinity are dying. Small holes appear in the bark, a reddish pitch exudes, the leaves turn brown, and in a few weeks the tree dies. I think the mischief is done by the small black insect inclosed herewith, which I found in one of the holes. Is there any remedy?

[a] Nineteenth Annual Report U. S. Geological Survey, 1897–98, Part V, pp. 67–164.



WORK OF THE PINE-DESTROYING BEETLE OF THE BLACK HILLS (DENDROCTONUS PONDEROSA N. SP.). PRIMARY GALLERIES AND LARVAL MINES IN INNER SURFACE OF LIVING BARK.

a, Entrance and basal chamber; *b*, ventilating holes in roof of gallery; *c*, termination. The larval mines radiate from the primary galleries. About one-half natural size. (Original.)



WORK OF THE COARSE-WRITING TOMICUS, IN INNER SURFACE OF BARK FROM DYING PINE.

a, Entrance; *b*, central chamber; *c*, primary or egg galleries. Reduced about one-half. (Original.)

THE TROUBLE CAUSED BY INSECTS.

The evidence obtained from a study of all stages of the afflicted timber, including the living, dying, recently dead, and old dead trees, of all sizes, and under widely varying conditions of altitude, exposure, geological formation, soil, and character of growth, indicates quite clearly that this widespread, unhealthy, dying, and dead condition of the timber is the work of insects.

THE PRIMARY ENEMY.

The evidence found also clearly indicates that the insect which makes the first attack on the living trees, and therefore the primary cause of the trouble, is a small, black, bark-boring beetle, belonging to a species heretofore unknown to science, and appears to be peculiar to the Black Hills region.[a]

NAME OF THE BEETLE.

Since this primary enemy has not been distinguished from a number of other bark beetles found in the infested trees, it has not been desig-

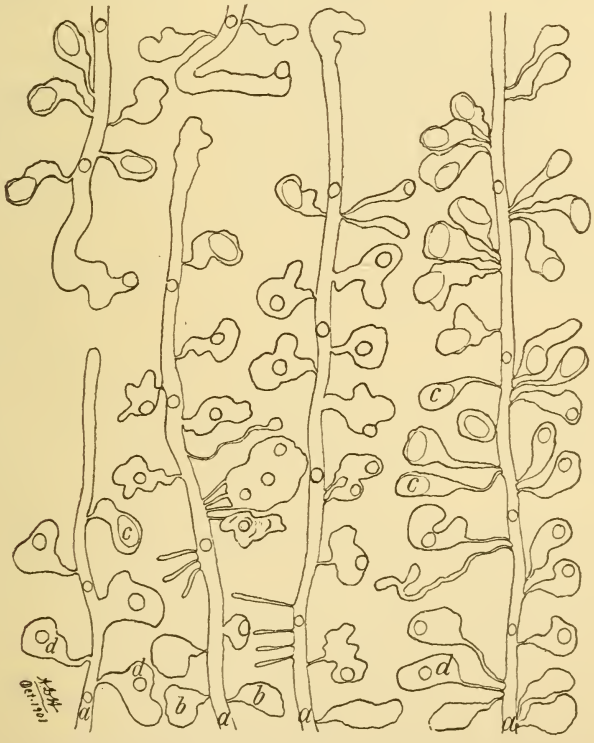


FIG. 1.—Work of the pine-destroying beetle of the Black Hills, in inner bark of dead tree. *a*, primary galleries; *b*, larvæ mines; *c*, pupæ chambers; *d*, exit holes. Reduced about one-half (original).

nated by a local name. I would therefore suggest that hereafter it be designated as "the pine-destroying beetle of the Black Hills," and by

[a] Since this was written it has been reported from Colorado.—A. D. H.

the technical or Latin name *Dendroctonus ponderosa.*[a] The adult is a stout, dark-brown to black beetle, individuals of which vary in length from 4 to 7 mm. (about one-sixth to one-fourth inch). They attack living and healthy large and small pine trees, enter the bark on the main trunk, and each pair excavates a long, nearly straight, longitudinal gallery through the inner bark (Pl. I and fig. 1), usually grooving the surface of the wood. Eggs are deposited along the sides of this primary gallery and hatch into minute white grubs (larvæ), which excavate mines through the bark at right angles to the primary gallery (fig. 1, *b*). These mines are extended and enlarged as the larvæ increase in size, and when full grown each individual excavates a broad, oval cavity in the bark (fig. 1, *c*), in which it transforms to a soft, white pupa, and then to the adult, which bores out through the bark (fig. 1, *d*), and flies, with other adults of the same and other broods, in search of other living trees in which to excavate galleries and deposit eggs for another brood.

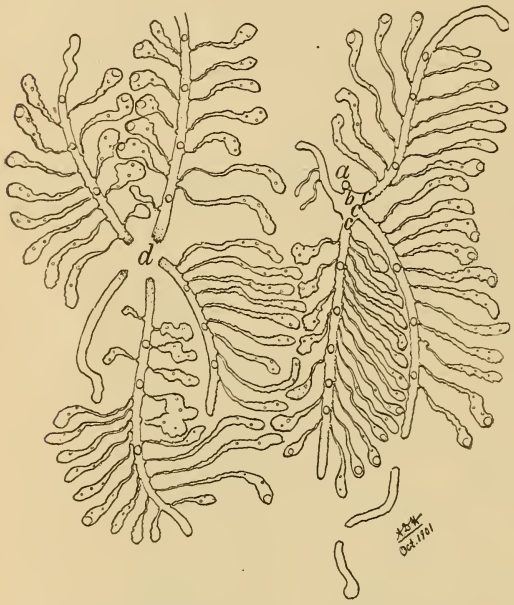


FIG. 2.—Work of the Oregon Tomicus (*Tomicus oregoni* Eichh.). Primary galleries and larval mines in inner bark. *a*, Entrance; *b*, central chamber excavated through inner bark; *c*, egg galleries; *d*, location of central chamber not excavated through inner bark. Reduced about one-half (original).

SECONDARY ENEMIES.

Many other species of bark beetles and other bark and wood infesting insects were found associated with the primary enemy in the partly living bark of infested and dying trees, but none of them were found making an independent attack on living trees. Therefore they must be considered as secondary enemies, which follow the leader in the attack, and merely contribute to the rapid and certain death of the trees thus infested.

The Oregon Tomicus (*Tomicus oregoni* Eichh.).—This is a small reddish to black bark beetle, individuals of which vary in length from 3.5 mm. to 4 mm. It follows closely the attack of the pine-destroying beetle, and enters the bark on the large and medium sized branches and toward the top of the main stem. Several females excavate radi-

[a] This species has heretofore been erroneously identified as *D. terebrans* and *D. rufipennis*, and will probably be found so labeled in some collections.

ating galleries from a single entrance and a central chamber (fig. 2, *a* and *b*). The central chamber may (*a*), or may not (*b*), extend through the inner layers of bark and groove the surface of the wood, but the radiating galleries are nearly always grooved in the surface of the wood, as are also the egg cavities, which are excavated at short intervals along the sides (figs. 3 and 4). These grooved and notched carvings are often very conspicuous in the surface of the wood of trees and logs for many years after the bark is removed or has fallen away. The number of galleries branching from the central chamber varies from two to five or six, but the normal number is four—two above and two below the entrance. The mode of development of the young stages is the same as in the preceding species. (See Pl. V.)

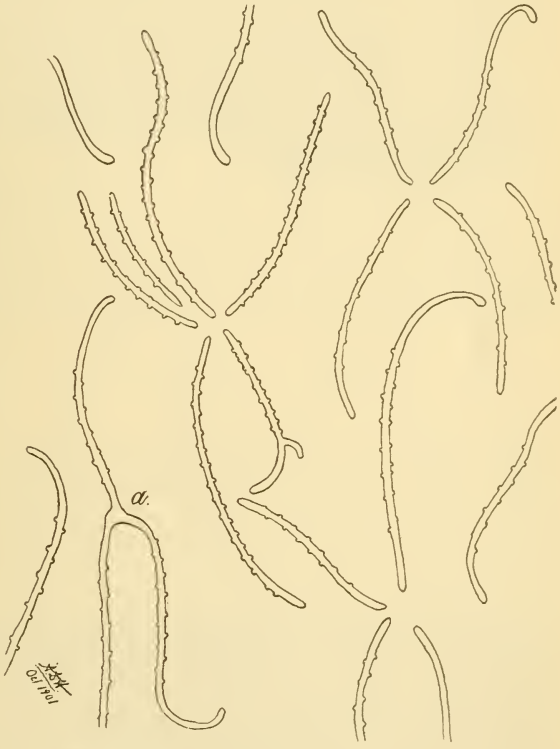


FIG. 3.—Work of the Oregon Tomicus. Primary galleries engraved in surface of wood. Central chamber not extending into wood except at *a*. Reduced about one-half (original).

This is a common enemy of the rock pine (*Pinus ponderosa scopulorum*) throughout the Rocky Mountain region and of *P. ponderosa* west of the mountains. It is ever ready to attack and prevent the recovery of trees of all sizes which are suffering from weakened vitality. It is also attracted to recently felled trees, and breeds in enormous numbers in the bark on the tops and branches. The species was found to be exceedingly common in trees infested by the pine destroyer and on the logs and tops of those felled by the lumbermen.

The coarse-writing bark-beetle (*Tomicus calligraphus* Germ. var. *occidentalis*).—This is much larger than the Oregon Tomicus, but is of the same color and general form. Individuals vary in length from 4.5 mm. to 6.5 mm. This species also follows closely the first attack by the pine destroyer. It enters the bark from near the base to toward the

top of the tree, and excavates three or four long longitudinal galleries from a single entrance and broad central chamber (Pl. II). The central chambers and galleries are usually grooved in the surface of the wood, but can be readily distinguished from those made by the Oregon Tomicus. It is a common and widely distributed species over the greater part of the pine-producing areas of the United States from the Atlantic coast to and including the Rocky Mountain region.[a] It attacks all of the Eastern and Southern pines, and doubtless several of the Western pines in addition to the rock pine, in which it was found in large numbers in the Black Hills region.

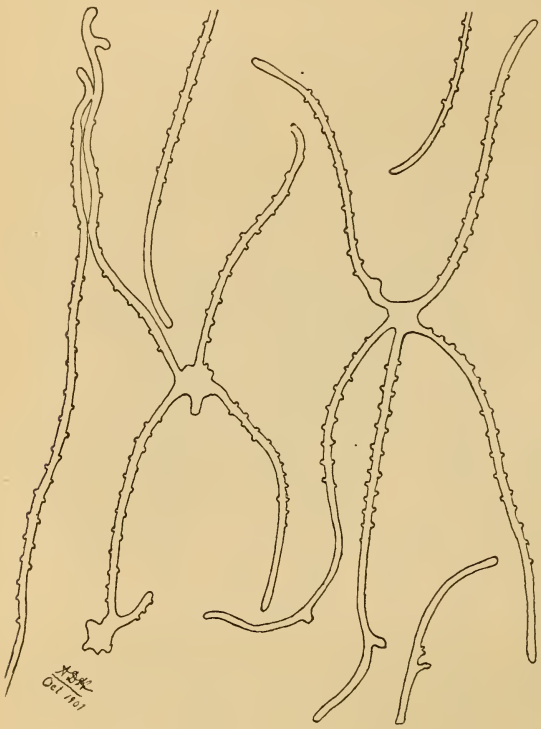


FIG. 4.—Work of the Oregon Tomicus. Primary galleries engraved in surface of wood. Central chamber extending into wood. Reduced about one-half (original).

The wood-engraving Tomicus (*Tomicus cælatus* Eichh.).—This is a much smaller and more slender bark beetle than the two preceding species. Individuals vary in length from 2.6 mm. to 3.2 mm., and in color from dark red to dull black. This is also a common, widely distributed, and variable species. It extends from the Atlantic to the Pacific, and infests all of the Eastern and Southern pines and spruces. A variety (var. *scopulorum* n. var.) was found in the rock pine of the Black Hills, and has been collected by the writer from a number of other species of Western pines. It attacks and breeds in the inner bark on the roots, trunks, and branches of weakened and dying standing trees of all ages and sizes, from the very young to the oldest and largest. It also breeds in immense numbers in the stumps, logs, and tops of recently felled trees.

The dark-red turpentine beetle (*Dendroctonus valens* Lec.)—This is the largest of the known North American bark beetles. The adults vary in length from 6 mm. to 9.5 mm. It attacks the bark on the base of liv-

[a] The Western form seems to be sufficiently different in some minor characters to warrant this distinction in variety name—*occidentalis*.

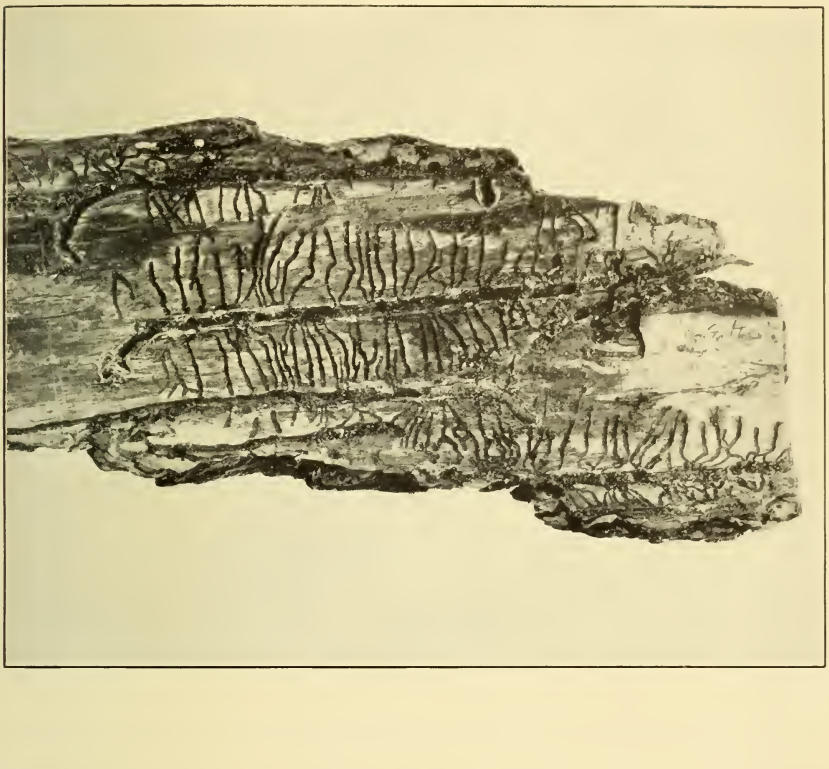


FIG. 1.—PRIMARY GALLERIES AND LARVAL MINES IN INNER BARK.

FIG. 2.—MARKS OF PRIMARY GALLERIES ON SURFACE OF SCORING

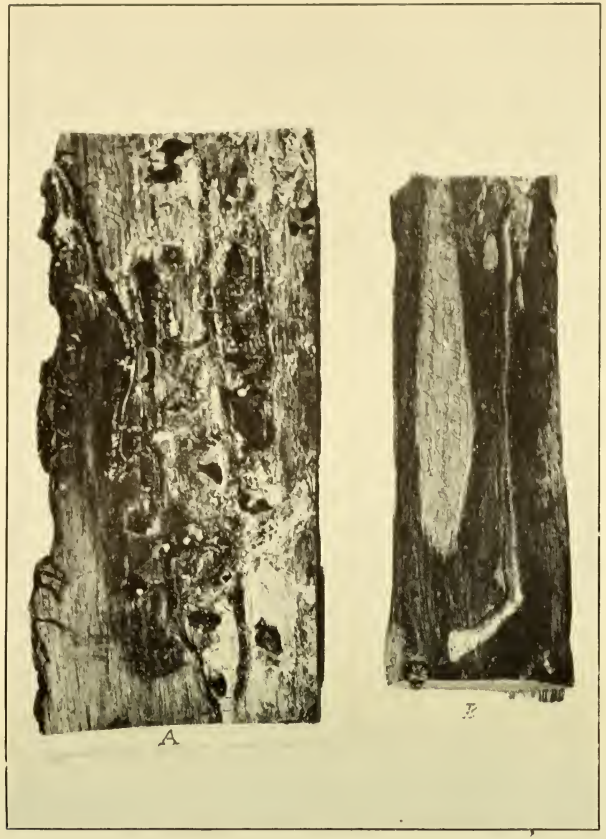


FIG. 1.—A, PRIMARY GALLERIES, LARVAL MINES, PUPA CASES, AND EXIT HOLES; B, PRIMARY GALLERIES GROOVED IN SURFACE OF WOOD IN CHIP CUT FROM RAILROAD TIE. (ORIGI-

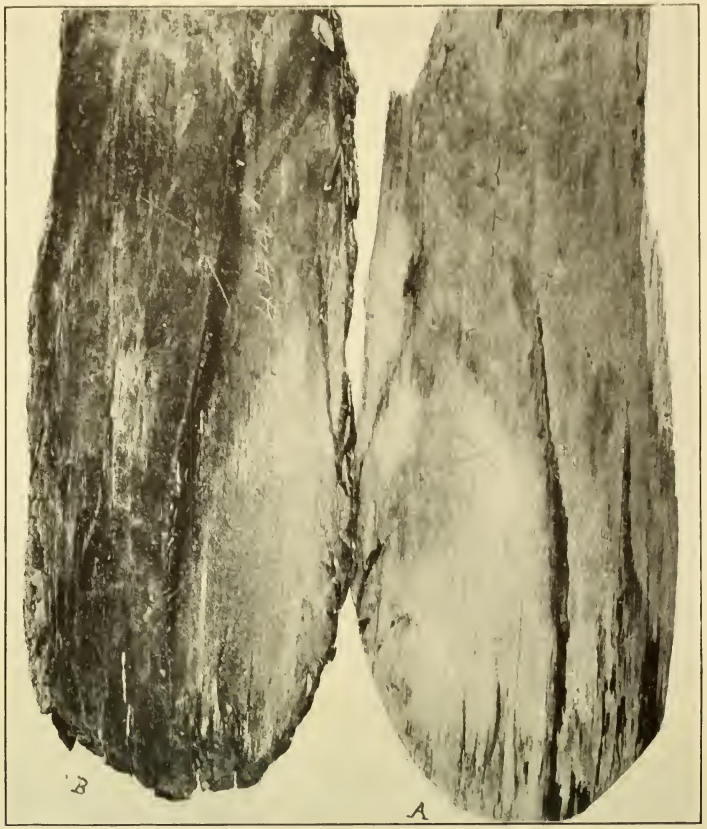


FIG. 2.—EVIDENCE OF CUTTING OF LIVING TREES. A, SCORING CHIP FROM RAILROAD TIE, SHOWING SURFACE OF WOOD NOT MARKED BY INSECTS; B, INNER SURFACE OF BARK FROM SAME CHIP. ABOUT ONE-THIRD

ing and dying standing trees and the stumps of felled ones, and excavates a broad, crooked, longitudinal gallery. The eggs are deposited in masses along one side, and when they hatch the larvæ work together and excavate a broad chamber, instead of making individual larval burrows, as is the rule with most other species. One of the striking peculiarities of this insect is the habit of the adult and larva of living in the quantity of semiliquid pitch or turpentine which accumulates in the primary gallery and brood chamber. While this beetle is capable of attacking and developing its broods in the bark of a living, healthy tree, it seldom causes the death of trees unaided by other insects. It does, however, contribute to the death of trees attacked by the pine-destroying and other destructive beetles. It is a common insect in the Rocky Mountain region and west to the Cascades. A variety (*Dendroctonus valens orientalis*) is common in the East, attacking in the same manner all of the Eastern pines.

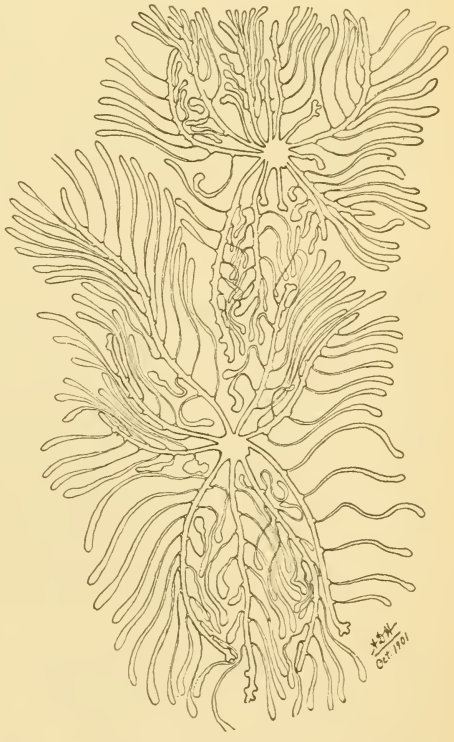


FIG. 5.—Work of the rock pine wood engraver (*Pityogenes carinicep*s Lec.). Primary galleries and larval mines in inner bark and surface of wood. Reduced about one half (original).

The Western pine Hylurgops (*Hylurgops subcostulatus* Mann.).—This is a common, dull brown to black bark beetle, ranging in length from 3.5 mm. to 4.5 mm., which attacks and breeds in the bark on the roots and bases of dying trees and the stumps and logs of felled ones. It excavates a single longitudinal gallery, and the broods develop in confused or irregular larval mines in the inner bark, but rarely groove the surface of the wood. This is one of the commonest bark beetles from the Rocky Mountain region to the Pacific coast, and will evidently be found wherever the rock pine or Western yellow pine grows.

The pine-root bark-beetle (*Hylastes porosus* Lec.).—This is a black, elongate, slender bark beetle, varying in length from 4 mm. to 5 mm. It attacks the bark on the roots of the Western pine and excavates a single longitudinal gallery from which the brood burrows radiate, and the broods develop in the usual manner. It was found in the bark on the roots of young seedling pines which had recently died,

and also in the bark on the roots of the stump of a recently felled tree in the Black Hills. This is also a common species of the Rocky Mountain pine regions.

Branch and twig beetles.—The large and small branches and terminal twigs of the trees that were dying from the attack of the pine-destroying beetle were found to be infested by a number of described and undescribed species of the genus Pityophthorus and by *Pityogenes carinicepsi*, all of which attack the bark as soon as the trees commence to die, and contribute, more or less, to hastening the death of the trees.

Ambrosia or timber beetles and wood-boring grubs.—The wood of the trees was found to be infested by the Western hemlock wood stainer (*Gnathotrichus sulcatus* Lec.), the Western pine wood stainer (*Gnathotrichus occidentalis* Hopk. MS.), and several unidentified Buprestid and Cerambycid larvae, which attack the trees, and when they commence to die bore into the sapwood and contribute to its rapid decay by giving entrance through their burrows to wood-decaying fungi.

SMALL TREES DYING FROM OTHER CAUSES.

The rock-pine pitch worm.—In addition to the trees killed by the pine-destroying beetle, quite a number of young pines 2 and 3 inches in diameter were found in the vicinity of Spearfish and Crow Peak that were seriously injured by the larva of an undetermined Sesiid moth working in the living bark of the main stem and causing ugly wounds. Successive attacks on the same tree weaken its vitality and attract the Oregon Tomicus and species of Pityogenes and Pityophthorus, which infest the main stem and branches, while a number of the root-infesting bark beetles and a pine weevil attack the base and roots, and the tree soon dies. Only a dead and dry larva and a dead chrysalis of this insect were found. The characters exhibited by these specimens do not agree with the descriptions of the larva of the sequoia and pine-destroying Sesiid (*Bembecia sequoia*= *Vespamima sequoiæ* Hy. Edw.[a]) or of the larva and chrysalis of the pine Sesiid (*Harmonia pini*=*Parharmonia pini* Kellicott[b]).

The destructive habits of this class of enemies of trees (which includes the common peach-tree borer) suggest that this may be a common and destructive enemy of "reproduction" pines in the Black Hills and other pine-producing areas of the West.

The pine weevil.—In another section near the Wyoming and South Dakota lines many young trees were observed which were apparently dying from the attack of a pine weevil (*Pissodes* sp.), or the combined attacks of this insect, a root fungus disease, and a number of species of bark beetles.

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[a] Mem. Am. Mus. Nat. Hist., vol. 1, part vi, Mongr. Sesiidæ. Am. North of Mex. 1901, p. 263, with bib. ref.

[b] Ibid., p. 264.

INSECT ENEMIES OF THE FOLIAGE.

Little time was had to collect or study the enemies of the foliage, but from general observations there was no perceptible injury from this class of depredators.

NATURAL ENEMIES OF THE DESTRUCTIVE AND INJURIOUS INSECTS.

Numerous species of predaceous and parasitic insects were found associated with the primary and secondary enemies. Some evidence was found of the beneficial work of birds, and a few examples of the pine-destroying beetle were found that had been killed by a disease, but in no case was there sufficient evidence to indicate that any of these natural enemies, or all combined, were in sufficient numbers to render any special service toward bringing the trouble to an end. They were undoubtedly rendering some service, however, in preventing the rapid multiplication of the pine destroyer, which would otherwise occur.

PREDACEOUS ENEMIES.

The bluish-green predaceous beetle (*Trogosita virescens* Fab.).—This is an elongate, flattened, shining, green beetle, varying in length from 10 mm. to 13 mm., and in width from 3 mm. to 4 mm. The larva is a long, slender, reddish to whitish worm, with shining black head and prothoracic plates. This recognized predatory enemy of bark-infesting insects was frequently found associated with colonies of the pine-destroying beetle and the secondary enemies, and a few adults were found hiding beneath the flakes of outer bark. This widely distributed insect in North America has not been sufficiently studied to determine its true relation to the destructive enemies of the trees, but it is evidently quite beneficial.

Clerid beetles and their larvæ.—The slender, reddish larvæ of undetermined species of this class of predaceous enemies of bark beetles were found in small numbers in the bark with the broods of the destructive and other species of bark beetles. This class of beneficial insects usually renders great service in reducing the numbers of the destructive and injurious species. Therefore their scarcity in this region may have had much to do with the rapid multiplication and spread of the pine-destroying Dendroctonus. While collecting specimens of bark beetles from saw logs in a mill yard at Boulder, Colo., on August 25, one of these Clerids (*Clerus nigriventris* Lec.) was very common. The active, ant-like adults, which are black, marked with transverse patches of gray, vary in length from 6 mm. to 8 mm., and in width from 2.5 mm. to 3 mm. The larva is a slender, pale red worm. The adult feeds on and destroys great numbers of the adult bark

beetles before they enter the bark and when they emerge, while the larva destroys the larva and broods in the bark.

A red-bug enemy of bark-beetles.—A small, red to brown Hemipterous bug of the family Acanthiidæ and subfamily Anthocorina was found in all stages of development, associated with colonies of the pine-destroying beetle and its allies, in the bark of recently attacked living and dying trees. These little relatives of the bedbug and the flower bugs are recognized as aggressive enemies of bark beetles, both in the East and West. The one found in the Black Hills is evidently *Pizostethus californicus* Reut. The adult is about 3 mm. long, slender, grayish, and exceedingly active. The young forms are usually bright red, active little creatures which attack and suck out the liquids from the bark beetles and their larvæ. The adult bug also attacks and kills the adult bark beetles. While this is a common and active enemy of the smaller bark beetle, it probably does not render much service toward checking the ravages of the destructive species.

Other predaceous beetles.—There are also a number of predaceous beetles of the families Colydiidæ, Tenebrionidæ, Histeridæ, and Staphylinidæ which were found in greater or less numbers in the bark of infested trees, but their exact relation to the destructive beetle was not determined.

PARASITIC INSECTS.

Several parasites belonging to the order Hymenoptera and families Braconidæ, Chalcididæ, and Proctotrupidæ were found to be enemies of the smaller bark beetle larvæ and adults, but none were found attacking the pine-destroying species. Therefore there does not seem to be much service rendered by this class of insects, which are usually so efficient in reducing the numbers of bark beetles.

PARASITIC FUNGI.

A few examples of the adults and larvæ of the pine-destroying beetle were found which had evidently been killed by a fungus disease, but this was by no means common enough to have rendered any service in checking its ravages.

BIRDS AS ENEMIES OF THE DESTRUCTIVE BEETLE.

A few old dead trees and some which had been recently infested which showed evidence of the beneficial work of woodpeckers were observed in some localities, but hundreds of other insect-killed trees showed no trace of work by the birds. Therefore there appears to be very little service rendered from this source. This is evidently due to a scarcity of the birds and to the fact that the habit of the insect transforming to the adult in the inner bark makes it less accessible to the birds than are the spruce-destroying beetle and other bark beetles which undergo this change in the outer bark.

Bul. 32, New Series, Div of Entomology, U. S Dept. of Agriculture.



FIG. 1.—A, GALLERIES ENGRAVED IN SURFACE OF WOOD CUT FROM OLD DEAD TREE; B BARK WITH INNER PORTION DESTROYED BY GALLERIES AND LARVAL MINES. ABOUT ONE-THIRD NATURAL SIZE. (ORIGINAL.)

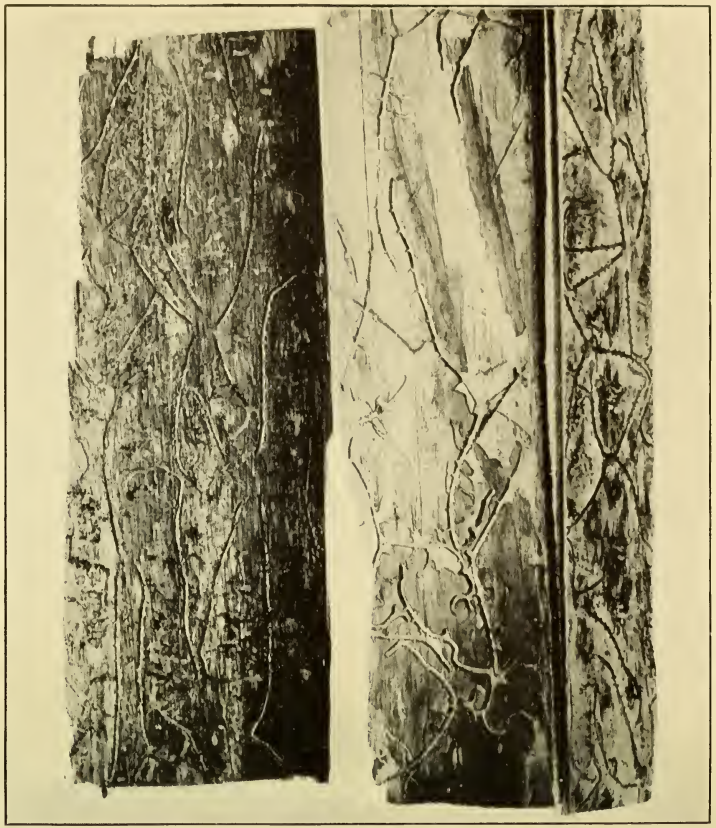


FIG. 2.—GALLERIES IN INNER BARK AND SURFACE OF WOOD OF RAILROAD TIES AND EDGING STRIPS. ABOUT ONE-THIRD NATURAL SIZE. (ORIGINAL.)



WORK OF THE ROCK PINE-WOOD ENGRAVER (PITYOGENES CARINICEPS LEC.). GALLERIES IN INNER BARK AND SURFACE OF WOOD. ABOUT ONE-THIRD NATURAL SIZE. (ORIGINAL.)



WORK OF THE ROCK PINE-WOOD ENGRAVER (PITYOGENES CARINICEPS LEC.). GALLERIES IN INNER BARK AND SURFACE OF WOOD. ABOUT ONE-THIRD NATURAL SIZE. (ORIGINAL.)

HOW THE TREES ARE ATTACKED AND KILLED.

Many hundreds of trees were examined during the investigation, including those that were living and perfectly healthy, living and freshly attacked, infested and dying, recently dead, and old dead ones which bore evidence of having been killed by the pine-destroying beetle. All stages of the insect, including the adult, the egg, different stages of the larva, the pupa, and recently transformed beetles, were observed and studied, as were also all stages of the primary entrance, the gallery and brood mines in the living, dying, and dead bark, and also the primary gallery grooves on the surface of the wood of old dead trees and logs from which the bark had fallen and decayed.

The evidences gathered from these studies, and from information conveyed in Mr. Dewey's letter, quoted on another page, indicate that the principal attack is made in August, when it would seem the beetles migrate in swarms from the dying trees and settle on the living ones, which they attack and infest in large numbers from near the base to the upper part of the main trunk or stem.

The trees that are attacked by a sufficient number of the beetles to overcome the resistance exerted by the vital forces of the plant commence to decline, and by winter or the following spring they die and the leaves turn yellow and red. Those not attacked by sufficient numbers of the beetles to overcome this vital resistance recover and are usually exempt from future attacks; the wounds heal and are covered over by subsequent layers of wood, thus causing pitch spots or gum-streak defects in the wood.

The details of the work of the attacking force of beetles on a living tree may be briefly described as follows:

Both sexes settle on their victim, usually in large numbers, and the males (?)[a] commence to excavate the entrance burrows, which are usually hidden in a crevice or beneath a flake of the outer bark. The reddish, sawdust-like borings thus produced and thrown out fall to the ground around the base and lodge in the loose outer bark on the trunk. When they enter the inner living bark, or bast, the tree commences to exert its resistance by throwing out pitch to fill and heal the fresh wounds in the living tissue. Then the struggle between the resisting force of the plant and the beetles begins in earnest. Each female joins her mate, and together they continue the excavation. The borings and pitch are disposed of by being pushed out and formed into a pitch tube at the mouth of the entrance burrow (Pl. VII, figs. 1, 3, and 4). The inner bark is entered obliquely and subtransversely to the cambium and surface of the wood, where a broadened cavity is excavated for the accommodation and temporary occupation of the

[a] While it was not positively determined that the male of this species excavates the first entrance, it is the habit of many other bark beetles, and is probably followed by this.

pair, probably until the principal flow of pitch is exhausted. The gallery is then extended (probably by the female) transversely or subtransversely for a short distance (seldom more than an inch), and then longitudinally up or down the tree, but usually up, varying from a few inches to a foot and a half, the normal length being about 1 foot. As soon as the gallery has been extended 1 or 2 inches from the entrance and basal cavity, small notches, or cavities, are excavated in the sides of the gallery, in each of which an egg is deposited, and so on until the gallery is completed. As the eggs are deposited, the borings, instead of being thrown out at the entrance, are closely packed in the entrance burrow, basal cavity, and gallery, except near the farther end, which is kept open, enlarged, or extended to one side or the other, as it is occupied by the parent beetles, after their work of constructing the egg gallery is completed, until they die (Pl. I).

The bark of an infested tree is usually occupied by one of these primary galleries in every 1 to 6 inches of circumference from near the base to near the middle of the trunk (Pl. VII, fig. 2). Therefore they effectually check the normal movements of the sap, and the larval mines, which radiate from the primary gallery, destroy the intervening bark and complete the girdling process.

Ten or twenty, or even forty or fifty pairs of beetles, attacking a tree 6 or 8 inches in diameter, would have little or no effect on its vitality if scattered over the trunk from the base to near the top, but if concentrated on a limited space on the upper part of the trunk, and distributed so that there is a gallery at intervals of about every inch of the circumference, forty or fifty galleries are sufficient to so seriously affect the tree that other insects are attracted to it, and it soon dies from the girdling effect of the primary galleries and brood mines. The marks of as many as seven galleries were observed in a single chip, 6 inches wide and 12½ inches long (Pl. III, fig. 2), cut from a tree that had been killed by the beetles. This, with many other observations relating to the number of pitch tubes on freshly attacked trees and the galleries in the bark of dead and dying ones, indicates that the average tree killed by the beetles has from one hundred to two hundred galleries in 30 to 40 square feet of bark from the middle to base of the main stem or trunk. The number of eggs deposited in each gallery depends on the number of galleries within a given area of bark and the success of the attack. They vary from one or two to about one hundred, but the normal number appears to be about forty to fifty. If only one-half of these develop to adults there are four thousand or five thousand beetles to emerge from a single tree 8 to 10 inches in diameter. Therefore the number of beetles that may emerge from the thousands of trees that die in a single year would make a swarm of millions of individuals. Even if this number were reduced one-half, it will be readily seen how the trouble may be rapidly extended over vast areas of forests.

CHARACTERISTIC FEATURES OF THE LIVING, DYING, AND DEAD TREES INFESTED AND KILLED BY THE BEETLE.

The characteristic features which are of importance to the forester and lumberman in identifying the presence and the work of the pine-destroying beetle are as follows:

BORINGS AND PITCH TUBES.

The first indication of attack is the red dust or borings lodged in the loose bark and fallen around the base of the tree. The next and more conspicuous evidence is the presence of numerous small masses of pitch or so-called pitch tubes on the outer bark at the mouth of the entrance burrows. (Pl. VII., figs. 1, 3, 4.) If the pitch is fresh and mixed with reddish and white borings, it indicates a recent attack and the presence of the living beetles in the bark. If, however, the pitch is dry and hardened, without traces of fresh borings or the presence of living beetles, and the tree is living, it indicates an abandoned attack and that the tree will recover.

APPEARANCE OF THE LEAVES.

The leaves of trees dying from attack by the beetle present first a pale-yellow appearance in the tops and tips of the branches, followed by a general yellowing of all the leaves, thus presenting from a long distance a marked contrast to the dark, healthy green of the surrounding living foliage. If the bark is stripped off and examined when the trees are in this condition, all stages from eggs to fully-developed broods will usually be found, together with numerous other secondary enemies of the trees and enemies of the insects. The leaves do not fall from the twigs for possibly two or three years after the trees die and the broods of beetles emerge, but they soon change from yellow to red, and thus become even more conspicuous. The normal length of time the leaves remain on the twigs has not been determined, but the greater number evidently fall during the second or third year, leaving the twigs almost bare, with the exception of a few leaves on the tips which may adhere for a much longer time.

APPEARANCE OF THE TREES THAT HAVE BEEN DEAD THREE YEARS OR MORE.

Little opportunity was had to obtain information on the characteristic appearance at different stages of deterioration, but it would appear from such observations and general comparisons as could be made that the twigs and some of the branches commence to fall within three or four years, and that after the fourth year rapid decay sets in, and the tops commence to break off.

EVIDENCE OF THE WORK OF THE BEETLE ON OLD DEAD TREES.

After the trees have been dead many years most of them decay at the base and fall, while the main trunks or snags of others remain standing; yet as long as the surface of the wood remains sound the characteristic longitudinal gallery grooves will be more or less distinct, and serve to indicate that the trees were attacked while living. Pieces of the old bark will also usually show traces of the galleries and indicate by the pitch-preserved tissue that the galleries were excavated in living bark. Traces of the pitch tubes may also remain on the outer bark for many years and serve to indicate the cause of the trouble.

RELATION OF WOOD-BORING INSECTS AND WOOD-DESTROYING FUNGI TO THE RAPID DETERIORATION OF THE WOOD.

As previously indicated, there are a number of wood-boring insects which bore into the sapwood of dying and dead trees. Some also penetrate the heartwood. Some of these wood-infesting insects enter the wood as soon as the tree commences to die, others after it is dead, and still others at different stages of the decline and decay as long as there is anything left for them to work in. It is only those, however, that enter the wood while it is yet of value for commercial purposes that need to be specially mentioned in this connection. Next to the one that makes the primary attack, those borers which enter the sound wood are probably of the greatest importance. They not only cause pin-hole and wormhole defects, which depreciate the value of the lumber and other products into which the wood of the dying and dead trees may be converted, but they give entrance to wood-decaying fungi, causing rapid decay of the wood of the standing trees which would otherwise remain sound for a much longer period.

While the injuries by these wood-boring insects are by no means as common where there are a great many dead and dying trees as where there are only a few, it was found to be sufficient in some sections to cause, in connection with the wood-decaying fungi, a worthless condition of the timber over large areas. Indeed, it would seem from such observations as we were able to make that unless the trees are cut and converted into lumber, ties, cordwood, or other commercial products within two or three years after they commence to die, very little of value is left.

SUGGESTIONS FOR PREVENTING LOSSES.

The limited time devoted to the study of this new insect was not sufficient to determine the details in its life history and habits which are usually so necessary in the consideration of remedies, but some general features were noted, which, in connection with the information acquired from special investigations of the closely related destructive

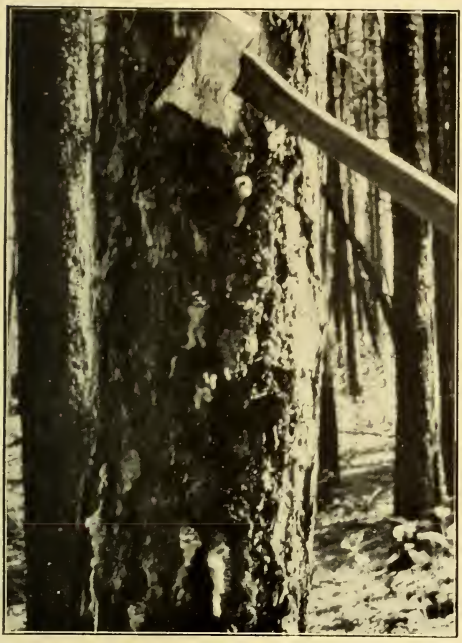


FIG. 1.—SMALL FRESHLY ATTACKED PINE TREE, SHOWING PITCH TUBES.

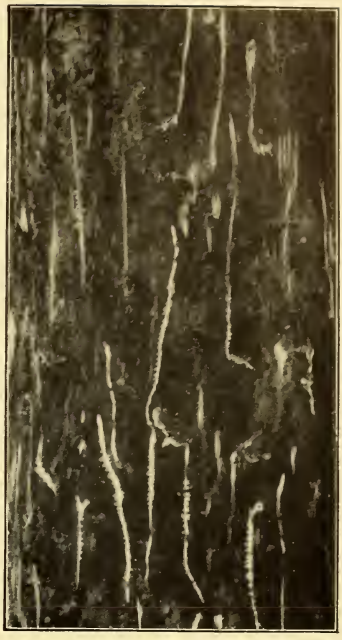


FIG. 2.—MARKS OF PRIMARY GALLERIES ON THE SURFACE OF WOOD WHEN BARK IS REMOVED.



FIG. 3.—FRESHLY ATTACKED TREE, SHOWING PITCH TUBES. ADJOINING TREE NOT ATTACKED.



FIG. 4.—DEAD TREE; OUTER BARK REMOVED BY WOODPECKERS.

SCENES IN THE PINE FORESTS OF THE BLACK HILLS FOREST RESERVE.

pine-bark beetle[a] of the middle Appalachian region and the spruce-destroying beetle[b] of the Northeast, will warrant, it is believed, some suggestions for the prevention of losses.

METHODS OF COMBATING THE ENEMY AND PREVENTING LOSSES FROM ITS RAVAGES.

When a trouble has been going on six or seven years and has reached the magnitude of the one under consideration, it is very plain that unless some natural agencies appear to either modify or check it, its control is beyond all human effort. On the other hand, if there are beneficial influences at work which are reducing the numbers of the insect and checking its destructive ravages, there is much that can be done toward aiding nature in the suppression and subjugation of an unruly species. The evidences found indicate that the latter is true in regard to this trouble. While many freshly attacked living trees and thickly infested dying ones were observed in different sections of the reserve, showing that great numbers of the beetles are at work and continuing the trouble, it was plain that the force of the attack has from some cause been materially weakened.

TO REDUCE THE NUMBERS.

It appears that the pine-destroying beetle of the Black Hills, like its Eastern relatives, depends on the trees killed by it for the augmentation of its numbers and the perpetuation of its power of killing more trees. Therefore it is only necessary that the attacking force be further reduced to a point where it can no longer overcome the vital resistance of the trees on which it concentrates its attack, in order to successfully defeat it and secure its extermination.

The fact that the attacking force of the enemy is already weakened from natural agencies suggests that they can be reduced by artificial means below their power of killing more trees next season, and thus bring the trouble to an end. Therefore the following are suggested and recommended as probably the best methods of accomplishing this result:

(1) Determine the location and extent of areas in which trees were attacked during the summer and fall of 1901 and the number of trees now infested with living broods of the pine-destroying beetle.

(2) Select those areas in which there are the largest number of infested trees and mark the same for cutting.

(3) Secure, by sale contracts or otherwise, the cutting of these trees and the removal of the bark from the infested parts of the main trunks and stumps prior to the 1st of May, 1902. The drying of the removed

[a] *Dendroctonus frontalis* (Zimm.) var. *destructor* Hopk., Bul. 56, W. Va. Agric. Exp. Station, 1899.

[b] *Dendroctonus piceaperda* Hopk., Bul. 28 n. s., Div. Ent., U. S. Dept. Agric., 1901.

infested bark and surface of the wood will effectually destroy the insects. In addition, the logs so treated will be protected next spring and summer from the attack of wood-boring insects, and thus be almost or quite as valuable for all commercial purposes as if cut from living trees.

It is not necessary that all infested trees in the reserve or those of all other infested areas should be thus cut and barked, but it is important that a large per cent should be so treated in order to insure a sufficient reduction of the beetles to check their destructive ravages.

SUGGESTIONS FOR PREVENTING FURTHER TROUBLE.

It is believed that the prevention of further trouble may be effected by means of girdled and otherwise treated trap trees, but the best method of treating the trees and the proper time or periods to do the work remain to be determined.

No experiments of this kind have been conducted with the rock pine, and it is not positively known when the beetles commence to fly or what is the period of their greatest abundance or swarms. Therefore it is suggested that a special line of experiments be conducted, between the 1st of May and the 1st of September, to determine the best methods of providing trap trees and the best time to do the work to secure the desired end, viz, that of attracting the migrating beetles to certain trees or sections of the forest, where they can be subsequently destroyed by cutting the trees and removing the bark.

TO PREVENT LOSSES FROM WOOD-BORING INSECTS AND WOOD-DESTROYING FUNGI.

The evidence found relating to the work of wood-boring insects and wood-destroying fungi, which cooperate in effecting a rapid deterioration of the trees killed by beetles, suggests that all trees should be cut within three or four years after they commence to die, the sooner the better, and be worked up into lumber, ties, mine timbers, and cord wood, in order to prevent the great loss of valuable products which would otherwise follow. Such material, if in excess of the demand for immediate consumption, might be stored where it would keep dry and be protected from fire. It would thus remain sound for many years and serve to supply the demand for material which would otherwise have to be drawn from the living timber.

THE PROTECTION OF LIVING TIMBER.

Since it is of the greatest importance that the living timber in the reserve should be protected and preserved for the heavy demands upon its resources which, owing to the vast mining, commercial, and other interests, it will be required to meet, the prevention of unnecessary cutting on account of injuries, or alleged injuries, from insects should receive special attention.

EVIDENCES OF UNNECESSARY CUTTING OF LIVING TIMBER.

One of the special objects of the investigation was to determine whether or not unnecessary cutting of living timber had been done by certain contractors who had purchased, at a reduced price, the specified "bug-infested" and "bug-killed" timber. Therefore, upon the request of Mr. Pinchot, the writer made a careful study of the conditions found in an extensive cutting in a "draw" east of Dead Ox Canyon of Big Spearfish Creek.

Much conclusive evidence was found that a large per cent of the trees cut here and worked into railroad ties had been living and uninjured by insects when felled. The evidence may be briefly stated as follows:

All trees that are attacked and injured by the pine-destroying beetle, whether in small or large numbers, plainly show the characteristic work of the beetles in the bark and on the surface of the wood, as previously described (p. 17) and illustrated (Pl. III, fig. 2; Pls. IV, VII). The character of the work will also indicate whether or not a given tree was living, dying, or dead when felled and the bark removed. The operation of scoring, hewing, and barking the ties in this particular cutting had evidently followed closely the felling of the trees. Therefore the inner portion of the bark and outer or adjoining portion of the wood of the scoring chips and the barked surface of the ties from "bug-infested" and "bug-killed" trees bore abundant evidence of the work of the insect and the condition of the tree when felled, while those from healthy living trees, not injured or infested by bark-boring insects, showed no traces whatever of the work of the beetle or of any other "bug" or insect.

The records of ties, counted as observed in the woods and examined for the work of insects, show that out of 207 ties only 55 bore evidence of having been cut from "bug-infested" and "bug-killed" trees, while the other 152 bore no evidence of insect work on the barked surface, but showed from the condition of this surface that they had been cut from healthy, living trees; also that some of the trees had been cut in the winter when the sap was down and that others had been cut in the spring when the sap was up and the bark would peel. Therefore it would appear that a large amount of living timber had been cut which it was plainly evident the Government desired should remain standing.

SUGGESTIONS CONCERNING TIMBER-CUTTING CONTRACTS.

In order to provide or guard against the cutting of living, uninfested trees, along with the seriously injured and dying ones, it might be suggested that it be plainly stated in contracts and instructions that no living tree shall be cut which does not show, in the inner bark next to the wood, the presence of large numbers of living insects, of the species known as the pine-destroying beetle, or any other insect or insects which may hereafter be designated as destructive enemies of the trees.

NEED OF FURTHER INVESTIGATION.

While considerable evidence was found during the time devoted to the investigation, there yet remains much to be determined by detailed study and experiments relating to the peculiar conditions which bring about the invasion of a rare or new insect and the conditions which contribute to its rapid multiplication and destructive work, as well as those which contribute to its decline and sudden disappearance. There are also many facts, yet to be determined, relating to the life history and peculiar habits of the pine-destroying beetle and other numerous enemies of the trees, and the natural enemies of such insects. The determination of these facts is very necessary in order to suggest the best methods of preventing losses in the future. It will also help us to utilize nature's methods of protecting such of the species as are of use to man and destroying those that are objectionable.

Cutting and barking the infested trees this winter would be an experiment of great importance, not only in its prospects of ending the trouble, but in demonstrating whether or not it is a practicable method to be adopted under similar conditions in the future. It will also be of interest, and probably of considerable economic importance, to note the effect that this process of insect destruction will have on the other injurious and beneficial insects involved.

The experiments of girdling, cutting, and treating trees with a view of rendering them attractive to the migrating beetles, and thus providing traps for them, is a line of work which should receive special attention next summer. It would serve to demonstrate, or at least indicate, several things which it is quite necessary to know in order to adopt successful methods of preventing future trouble from insect ravages on the pines of this reserve. It would demonstrate whether or not the beetles that emerge from the infested trees which have not been cut and barked could be attracted to trap trees; how and when the rock pine can be girdled or treated to exert the greatest attraction to the principal enemies, and how the insects thus trapped can be best destroyed. It would also contribute greatly to the study of the life history and habits of the primary and secondary enemies of the trees and the enemies of the insects.

There are other features relating to the kinds of insects and fungi that attack trees girdled by different methods, or girdled and felled at different times of the year, which should be determined. Indeed, there are many and varied subjects relating to the insects of the rock pine which should be studied during the progress of the present trouble, in order to accumulate data that will be of service in preventing and checking future destructive invasions in the pine forests of the Rocky Mountain region.

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